

United States Patent

[11] 3,548,792

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 [21] Appl. No. 798,317
 [22] Filed Feb. 11, 1969
 [45] Patented Dec. 22, 1970

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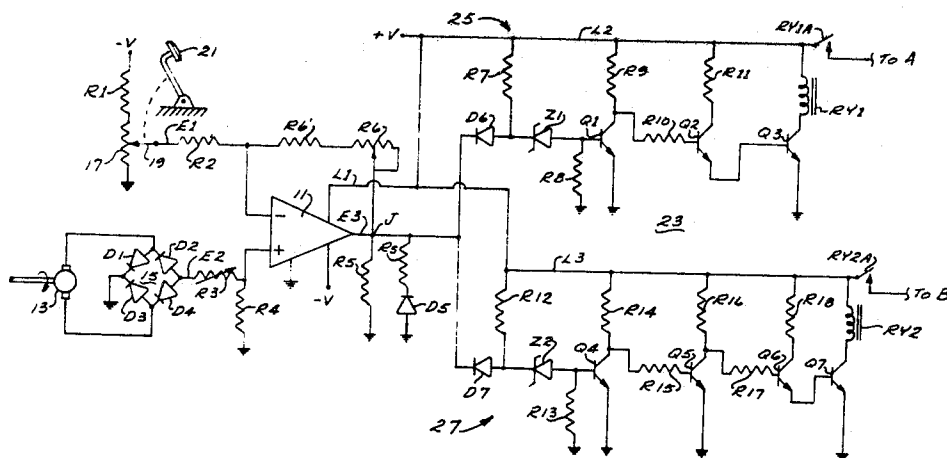
[54] CONTROL APPARATUS FOR INTERNAL-COMBUSTION ENGINES

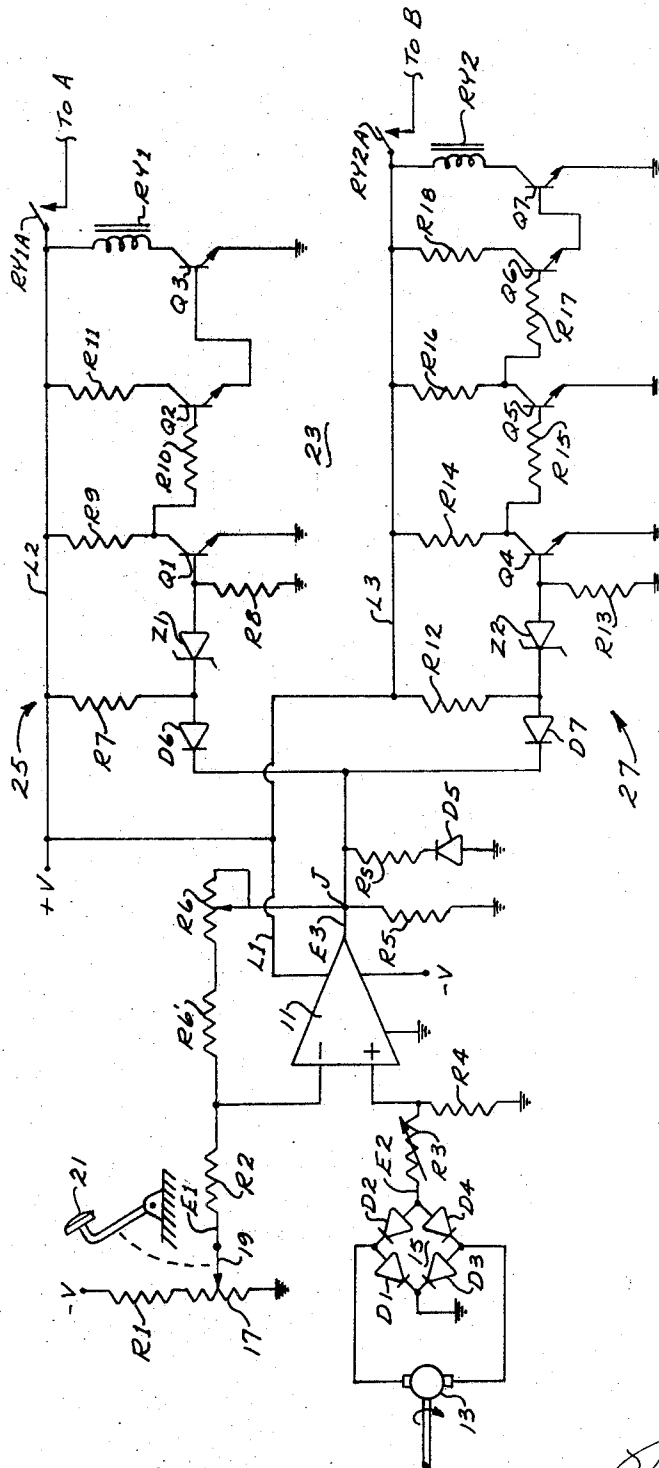
10 Claims, 2 Drawing Figs.

[52] U.S. CL..... 123/32,
 123/97B, 123/119, 261/121.2
 [51] Int. Cl..... F02d 5/00
 [50] Field of Search..... 123/32E,
 32E1, 119, 97B; 261/42, 121.1, 121.2

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ABSTRACT: A fuel control varies the fuel-air ratio of a throttled internal combustion engine in response to its operating parameters. The apparatus includes voltage comparing means providing an output voltage which varies as a function of the difference between first and second input voltages provided thereto. The first input voltage varies as a function of the rotational speed of the engine while the second voltage varies according to the throttle opening of the engine. A sensor is responsive to the output voltage of the comparing means and supplies control signals to means for controlling fuel leaning and enriching mechanisms, the control signals being predetermined functions of both the rotational speed and the throttle opening of the engine, thereby decreasing or increasing the fuel-air ratio according to the power demanded of the engine.





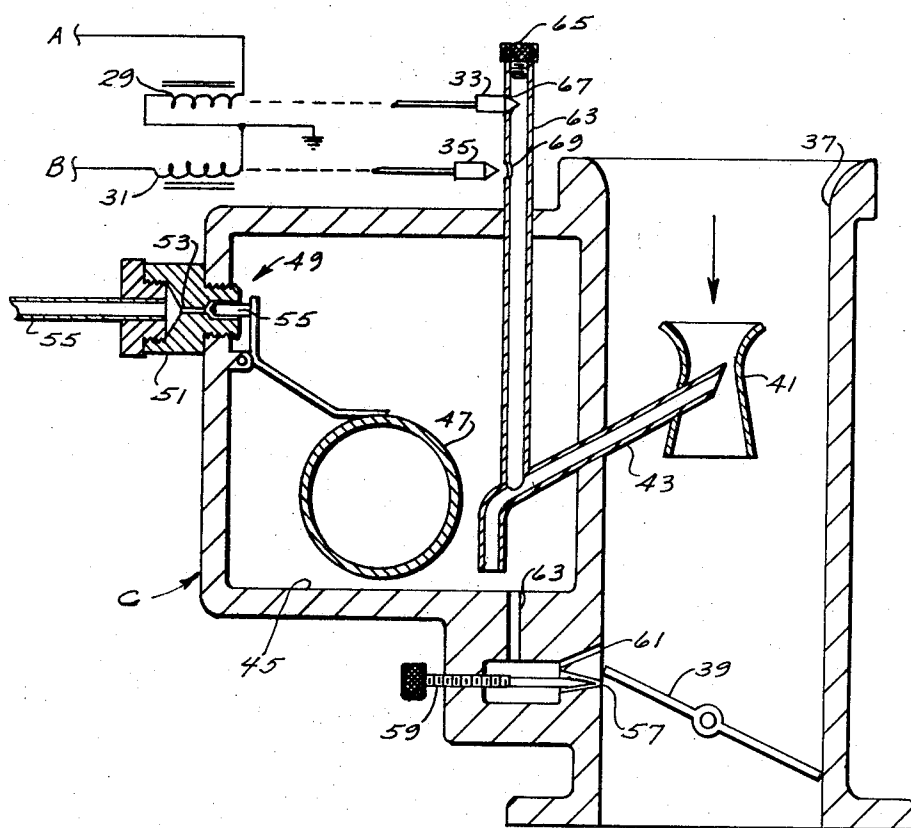


FIG. 2

CONTROL APPARATUS FOR INTERNAL-COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

This invention relates to control apparatus responsive to the power output demanded of a throttled internal combustion engine operable at different rotational speeds, and more particularly to a fuel control for varying the fuel-air ratio of such an engine in response to the operating parameters thereof.

The constantly increasing number of automobiles in our society, particularly in urban centers of population, has caused growing concern in both public and private sectors because of the pollution caused by automobile exhaust fumes. This has led to increased emphasis on ways of reducing undesirable exhaust emission. From this have resulted increasingly stringent requirements for improved control of fuel-air ratios for automobile engines. The fuel-air ratio of an internal combustion engine, i.e., the amount of fuel supplied to an engine in relation to the amount of air drawn into it, ideally should be maintained at values which, for all intended phases of engine operation, will prevent exhaust emission of unburned fuel and other byproducts of combustion from exceeding predetermined levels. If the fuel-air ratio is greater than that value which will present an amount of fuel which will be essentially completely consumed during combustion, then a wasteful surplus of fuel together with undesirable products of incomplete combustion will be discharged into the atmosphere through the engine's exhaust system.

Mass production economics make it desirable to use carburetors, as distinguished from fuel injection controls, for the great majority of production automobiles. While fuel injection controls lend themselves quite readily to accurate control of the fuel-air ratio in accordance with the power demanded of an engine, carburetors suffer certain disadvantages. In general, carburetors provide fairly nonuniform regulation of the fuel-air ratio in accordance with the power demanded of an engine. For example, if an engine is expected to deliver high power, as in powering a truck, the fuel-air ratio provided by the carburetor must be sufficiently high to prevent detonation when great power is demanded of the engine. In this case, the engine provides low power when pulling a light load or when coasting so that the fuel-air ratio will be unnecessarily high, permitting emission of unburned fuel and other noxious byproducts of incomplete combustion. On the other hand, if the fuel-air ratio is adjusted to provide a fuel-air ratio which will permit good combustion at low power demands, then detonation will occur when high power is demanded of the engine. In other words, it is desired that the fuel-air ratio be increased, i.e., the fuel mixture be enriched, as greater power is demanded of the engine. Correspondingly, when less power is demanded of the engine, it is desirable that the carburetor reduce the fuel-air ratio to provide a leaner fuel-air mixture.

Heretofore, approaches at reducing the amount of unburned fuel emission for engines utilizing carburetion have typically involved "brute force" techniques, such as providing an engine with an air injection pump for optimizing the fuel-air ratio while it is operating at low rotational speeds, providing labyrinthian intake manifold heating passages, and requiring the manufacture and adjustment of carburetors to costly precision tolerances. Typically, these approaches, while generally improving the fuel-air ratio, sacrifice engine power. With fuel injected engines, quite elaborate electronic controls for optimizing fuel-air ratios have been provided at considerable expense.

SUMMARY OF THE INVENTION

Among the several objects of the invention may be noted the provision of control apparatus for an internal combustion engine operable at different rotational speeds for varying the fuel-air ratio supplied to the engine in response to the operating parameters thereof; the provision of such apparatus which will decrease the fuel-air ratio when low power is demanded of the engine; the provision of such apparatus which will increase

the fuel-air ratio when high power is demanded of the engine; the provision of such apparatus which is operable to reduce the emission of unburned fuel and byproducts without sacrificing engine power; the provision of such apparatus which is operable to improve fuel economy; the provision of such apparatus which is operable to lean or to enrich the fuel mixture supplied by the carburetor of the engine thereby to more nearly optimize the fuel-air ratio in accordance with the power demanded of the engine; the provision of such apparatus which is particularly well-suited for use with carbureted automobile engines; and the provision of such apparatus which is relatively inexpensive, simple and reliable in operation. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, a fuel control of this invention varies the fuel-air ratio of a throttled internal combustion engine operable at different rotational speeds in response to the operating parameters of the engine. The control includes voltage comparing means providing an output voltage which varies as a function of the difference between two input voltages applied thereto. Means responsive to the rotational speed of the engines generates a first input voltage for the voltage comparing means, and means responsive to the throttle opening of the engine provides a second input voltage for the voltage comparing means which varies as a function of the throttle opening. A sensor is responsive to preselected values of the output voltage of the voltage comparing means and supplies control signals corresponding to preselected values of the output voltage, these control signals thereby being supplied according to the power demanded of the engine. Means is provided for controlling a fuel leaning mechanism in response to a first control signal which indicates a low power demand of the engine thereby decreasing the fuel-air ratio. Means for controlling a fuel enriching mechanism of the invention responds to a second control signal which indicates a high power demand of the engine and thereby increases the fuel-air ratio of the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 together are a circuit schematic diagram of control apparatus of this invention with fuel leaning and fuel enriching mechanisms thereof connected for controlling the fuel-air ratio of a carburetor viewed in cross section.

Corresponding reference characters indicate corresponding parts throughout the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and particularly to FIG. 1, there is illustrated a control of this invention which is utilized as a fuel control to vary the fuel-air ratio supplied to a throttled internal combustion engine operable at different rotational speeds. This is accomplished by altering the fuel mixture supplied to the engine by a carburetor (illustrated in FIG. 2) in response to the varying operating parameters of the engine which indicate the power demanded of the engine. The control includes a differential amplifier 11 such as an integrated circuit monolithic operational amplifier known to individuals skilled in the electronics art. This device is employed as a voltage comparing means and has a single output voltage which varies as a function of the difference between two input voltages provided thereto. An AC tachometer generator 13 driven by the engine and rectifier bridge circuit 15 for rectifying the AC voltage supplied by the generator 13 together comprise means responsive to the rotational speed of the engine for generating a first input voltage for differential amplifier 11. A potentiometer 17 having a wiper arm 19 actuated by, for example, the accelerator pedal 21 of a vehicle powered by the engine, constitutes means responsive to the throttle opening of the engine for providing a second voltage for differential amplifier 11, this voltage varying as a function of the throttle opening. Indicated generally at 23 is a circuit which operates as a sensor responsive to a preselected value of the output

voltage of the differential amplifier 11 for supplying control signals which correspond to respective preselected values of the output voltage provided by differential amplifier 11. These control signals are predetermined functions of both the rotational speed and throttle opening of the engine so that the control signals are supplied according to the power output demanded of the engine when in operation. Sensor 23 includes a fuel leaning circuit 25 and a fuel enriching circuit 27 which are connected to respective means for controlling fuel leaning and enriching mechanisms of the engine. The fuel leaning means comprises a leaning solenoid 29, and the fuel enriching means comprises a fuel enriching solenoid 31. Solenoids 29 and 31 operate respective air bleed valves 33 and 35 to vary the fuel-air ratio of the fuel-air mixture supplied to the engine by a carburetor indicated generally at C.

Referring specifically to the circuit shown in FIG. 1, potentiometer 17 is connected between ground and a negative DC power source, designated $-V$, through a limiting resistor R1. The wiper 19 of potentiometer 17 is connected so that it is operated in accordance with the throttle opening of the engine, for example, by a linkage with the accelerator pedal 21, so that depressing pedal 21 to open the engine throttle will cause the voltage E1 on wiper 19 to increase negatively. Wiper 19 is connected through a resistor R2 to the so-called inverting terminal of differential amplifier 11. This terminal is designated with a minus sign. The other terminal, designated with a plus sign, is the so-called noninverting terminal of the amplifier. To this terminal is connected the rectified output of diode bridge circuit 15. Bridge circuit 15 comprises four diodes D1-D4, the bridge being connected in conventional fashion to supply a full-wave rectified DC output voltage E2. This voltage is dropped across a voltage divider comprising an adjustable resistor R3 and a resistor R4 and is applied to the noninverting terminal of differential amplifier 11.

Tachometer generator 13 is a conventional type, suitably driven from the crankshaft of the engine. Its output voltage varies proportionally with the r.p.m. at which it is driven, i.e., it varies as a function of the rotational speed of the engine. It will be understood that, rather than a tachometer generator, a conventional electronic tachometric circuit may instead be employed for supplying a voltage which is a function of engine rotational speed.

Differential amplifier 11 is provided with connections to a negative DC power source, designated $-V$, by means of a lead L1 and to a positive DC power source, $+V$. A ground terminal is also provided. The output terminal of differential amplifier 11 is connected to a junction J which is biased to ground through a resistor R5 and connected through an adjustable resistor R6 and a resistor R6' to the inverting terminal of the differential amplifier. Resistors R6 and R6' provide means for adjusting the gain of the differential amplifier. Also connected between junction J and ground is a resistor RS in series with a diode D5 which, together, provide means for preventing the output voltage E3 of the differential amplifier which appears at junction J from becoming negative. The output voltage E3 is supplied to both the fuel leaning circuit 25 and fuel enriching circuit 27 of the sensor 23, each of which comprises, in effect, an individual sensing circuit. Fuel leaning circuit 25 includes a diode D6 which is connected between the output of differential amplifier 11. The cathode of diode D6 is connected to the anode of a Zener diode Z1 whose anode is connected to the base of a transistor Q1. The breakdown voltage of Zener diode Z1 determines a preselected level of the output voltage E3 of differential amplifier 11 at which fuel leaning circuit 25 is operative to reduce the fuel-air ratio of the fuel mixture supplied to the engine. A biasing resistor R7 is connected between the junction of diodes D6 and Z1 to a power supply lead L2 which provides a connection to the positive DC power source, designated $+V$. The base of transistor Q1 is biased to ground through a resistor R8 and its collector is connected to supply lead L2 by means of a resistor R9. Transistor Q1, connected in common-emitter configuration, provides an amplifier stage whose output is connected by means of a re-

sistor R10 from the collector of transistor Q1 to the base of transistor Q2, whose collector is connected to supply lead L2 by means of a resistor R11. The emitter of transistor Q2 is connected directly to the base of a transistors Q3, transistors Q2 and Q3 thus comprising a Darlington-coupled pair to operate a relay RY1 whose winding is connected between supply lead L2 and the collector of transistor Q3. The emitter of transistor Q3 is connected to ground. Relay RY1 includes a set of normally open contacts RY1A which, when closed, connect the DC voltage appearing on lead L2 to solenoid 29 (FIG. 2) for operating air bleed valve 33.

Fuel enriching circuit 27 is connected to differential amplifier 11 by means of a diode D7. This diode is in turn connected through a Zener diode Z2 to the base of a transistor Q4. Zener diode Z2, analogously to Z1, determines the preselective level of the output voltage E3 of the differential amplifier at which the fuel enriching circuit 27 is operative. The junction between the anode of diode D7 and cathode of Zener diode Z2 is connected to a supply lead L3 by means of a resistor R12. Supply lead L3, like supply lead L2, is connected to the positive DC power source designated $+V$. The base of transistor Q4 is biased to ground by means of a resistor R13 and its collector is connected to supply lead L3 by means of a biasing resistor R14, its emitter being connected directly to ground. Transistor Q4 provides a signal inverting stage for a purpose which will be explained hereinafter. Its collector is connected by means of a resistor R15 to the base of a transistor Q5. Transistor Q5, which provides an amplifier stage, has its emitter connected directly to ground providing a common-emitter configuration. Its collector is connected to supply lead L3 by means of a biasing resistor R16, and by means of a resistor R17, to the base of a transistor Q6. The collector of transistor Q6 is connected to supply lead L3 by means of a resistor R18 and its emitter is Darlington-coupled directly to the base of the transistor Q7. Connected between supply lead L3 and the collector of transistor Q7 is the winding of a relay RY2 having a set of normally open contacts RY2A which, when closed, connect the DC voltage on supply lead L3 to fuel enriching solenoid 31 to close the enriching air bleed valve 35.

A control of this invention alters the fuel-air ratio supplied to an engine by the carburetor C shown in cross section in FIG. 2. Carburetor C which is representative of a number of different types of carburetors with which this invention may be employed, includes a venturi 37 through which air is drawn in the direction shown by the arrow by operation of the engine. The volume of air drawn through venturi 37 is controlled by a butterfly throttle valve 39 linked to accelerator pedal 21. Within venturi 37 is a booster venturi 41 to which fuel is supplied by means of a fuel delivery tube 43 from a supply of fuel in a chamber 45. When air is drawn into venturi 37, and thereby booster venturi 41, a partial vacuum is induced by a pressure differential in the booster venturi, thereby drawing fuel through fuel delivery tube 43. The level of fuel in chamber 45 is controlled by a conventional hollow float 47 which operates a valve assembly indicated generally at 49, comprising a valve seat 51 having a fuel passage 53 closed by a float needle 55 operated by float 47 to prevent further fuel from entering float chamber 45 when there is sufficient fuel in the chamber. A fuel line 55 supplies fuel to the carburetor. The carburetor also typically includes a low speed idle jet 57 for supplying fuel for idling of the engine when valve 39 is closed, the flow of fuel through idle jet 57 being controlled by an adjustable needle valve 59. A high idle jet 61 provides additional fuel when throttle valve 39 is partially open. Fuel is supplied to jets 57 and 61 by means of a passage 63 communicating with float chamber 45.

In accordance with the invention, fuel delivery tube 43 is provided with an air bleed manifold 63 comprising a tube having its lower end communicating with fuel delivery tube 43 and an upper end which is closed, as by means of a plug 65. Tube 63 has a pair of air bleed holes 67 and 69 which can be closed by air bleed valves 33 and 35, respectively. When not

closed by these bleed valves, each of the bleed holes allows a predetermined amount of bleed air to be drawn into tube 63 thereby reducing the partial vacuum induced in fuel delivery tube 43 by the passage of air through booster venturi 41. It will therefore be seen that opening of either or both of the air bleed holes 67 and 69 will cause a reduction in the fuel-air ratio of the combustion mixture supplied by the carburetor to the engine. As is illustrated in FIG. 2, air bleed valve 33 is normally closed and air bleed valve 35 is normally open, to supply a "normal" fuel-air ratio.

Operation of the fuel control of this invention is as follows:

As is known to those skilled in the art, the output voltage E3 of differential amplifier 11 will be directly proportional to the difference between the voltages applied to its two input terminals. Specifically, output voltage E3 is determined by the following equation:

$$E3 = \frac{R2 + R6 + R6'}{R2} \left[\frac{R4}{R3 + R4} \cdot E2 - \frac{R6 + R6'}{R2 + R6 + R6'} \cdot E1 \right]$$

In order to understand how output voltage E3 is caused to vary and the manner in which sensor 23 responds to this output voltage, it is helpful to analyze the operation of the control in terms of the various phases of operation of the engine with which it is used.

It may first be assumed that the engine is idling. Accordingly, accelerator pedal 21 is in its fully released position so that wiper 19 and therefore voltage E1 are at a relatively small negative potential. Since the rotational speed of the engine is low (being determined chiefly by the setting of idle valve 59 which controls the flow of fuel through idle jet 57), tachometer generator 13 delivers a relatively low voltage. The output voltage of differential amplifier 11 is therefore only a small positive voltage or perhaps tends even to be a small negative voltage. Output voltage E3 is prevented, however, from becoming negative because such a voltage forward biases diode D5, causing it to become conductive. Therefore voltage E3 is substantially a zero or low positive potential. The output of differential amplifier 11 is coupled through diode D6 to the fuel leaning circuit 25 and diode D7 to the fuel enriching circuit 27. Zener diode Z1 is chosen to have a breakdown voltage such that the diode will not conduct in its reverse direction until output voltage E3 reaches a predetermined level. This level may be, for example, 2 volts. Thus, since voltage E3 is at a substantially zero or low positive potential, then diode Z1 does not conduct. Accordingly, no bias current is applied to the base of transistor Q1, which is therefore nonconductive. Because the collector of transistor Q1 is at a relatively high potential, biasing current is applied through resistors R9 and R10 to the base of transistor Q2 which thereby becomes conductive. This supplies current to the base of transistor Q3 to cause it also to become conductive. When transistor Q3 becomes conductive, the winding of relay RY1 is energized, thereby closing its contacts RY1A. This supplies a leaning control signal by connecting the supply voltage +V to leaning solenoid 29. Operation of solenoid 29 causes the opening of air bleed valve 33 thereby opening air bleed hole 67. Since bleed holes 67 and 69 are now both open, air at atmospheric pressure is permitted to bleed through both bleed holes causing a considerable reduction in the partial vacuum in fuel delivery tube 43. Thus the fuel-air ratio supplied by booster venturi 41 is reduced. However, since throttle valve 39 is closed the fuel is principally supplied by idle jet 57.

Assume that while the engine continues to idle, accelerator pedal 21 is depressed partly or fully. This causes opening of throttle 39 and moves wiper 19 of throttle potentiometer 17, thereby increasing negative voltage E1. Since voltage E2 is a relatively low negative potential, the difference between voltages E2 and E1 is increased in a positive sense. The output voltage E3 of differential amplifier 11 thereby becomes positive. When it exceeds the breakdown voltage of Zener diode Z1, the diode becomes conductive thereby applying a biasing current to the base of transistor Q1, causing it to become con-

ductive. When transistor Q1 conducts, bias current is drawn away from the base terminal of transistor Q2 which then becomes nonconductive, depriving the base of transistor Q3 of biasing current. This causes transistor Q3 to become nonconductive, deenergizing relay RY1. Relay contacts RY1A are thereby opened to deenergize leaning solenoid 29. This permits closure of leaning valve 33, once more closing air bleed hole 67. Air bleed valves 33 and 35 are then in the position shown in FIG. 2. Since the amount of air which can bleed into air bleed manifold 63 is now determined solely by air bleed hole 69, the partial vacuum in fuel delivery tube 43 is increased accordingly. Thus the fuel-air ratio mixture supplied to the engine by air drawn through booster venturi 41 is increased to its normal value.

If accelerator pedal 21 is further depressed while the engine is at idling speed, the output voltage E3 of the differential amplifier has an even greater positive level. The breakdown voltage of Zener diode Z2 is chosen at some level greater than that of diode Z1. It may be chosen, for example, to be 3 volts. Thus when output voltage E3 reaches 3 volts, diode Z2 breaks down and thereby supplies bias current to the base of transistor Q4 to cause it to become conductive. When it does so, bias current is conducted away from the base of transistor Q5 to cause it to become nonconductive. Since the collector of transistor Q5 is then at a relatively high potential, bias current is applied through resistor R17 to the base of transistor Q6 which then becomes conductive, causing transistor Q7 in turn to become conductive. Conduction of transistor Q7 causes energization of the winding of relay RY2, closing its contacts RY2A to supply an enriching control signal by connecting the positive DC power source +V to the fuel enriching solenoid 31. When solenoid 31 is energized, fuel enriching valve 35 is closed, covering air bleed hole 69. Air is thus prevented from bleeding through the air bleed holes 67 and 69. Because of this, the partial vacuum in fuel delivery tube 43 is determined solely by the amount of air drawn through booster venturi 41. In other words, when accelerator 21 is even further depressed indicating still greater power demand, the fuel-air ratio is increased correspondingly with this increased power demand.

It may be seen from the above that fuel leaning circuit 25 ceases to be operative when output voltage E3 exceeds the breakdown voltage of Zener diode Z1, but that, by virtue of the signal inversion provided by transistor Q4, fuel enriching circuit 27 becomes operative only when output voltage E3 exceeds the breakdown voltage of Zener diode Z2. Because of this on-off operation, it may be seen that the leaning and enriching control signals are nonlinear functions of the rotational speed and throttle opening of the engine.

Assuming that the engine has now accelerated to a normal modest speed, i.e., is turning at a moderate r.p.m., then accelerator 21 and therefore throttle valve 39 are at a position corresponding with the load which the engine is pulling. Thus, if throttle 39 is partly open, i.e., if accelerator pedal 21 is partly depressed, then voltage E1 has a relatively moderate negative value. At this normal engine speed, voltage E2 supplied by generator 13 and its rectifying bridge 15 has a relatively moderate value. Depending upon the values of resistors R3 and R4, this voltage may be slightly less than E1. Since the difference between these two voltages is therefore a relatively small positive potential, the output voltage E3 of the differential amplifier is a relatively low voltage which is somewhat greater than the breakdown voltage of Zener diode Z1 but less than the breakdown voltage of diode Z2. Thus, since neither the leaning circuit 25 nor the enriching circuit 27 is energized, the fuel mixture supplied to the engine by carburetor 37 has a normal fuel-air ratio. If a slightly higher power demand is required of the engine, as where it is pulling a vehicle up a hill, then accelerator pedal 21 is depressed still further thereby opening throttle 39 an additional amount and moving wiper 19 so that voltage E1 is somewhat decreased. This increases the potential difference across the input terminals of differential amplifier 11 and thereby increases its output voltage E3. When output voltage E3 exceeds the breakdown volt-

age of Zener diode Z2, fuel enriching circuit 27 is operated in the manner previously described because operation of fuel enriching solenoid 31 causes closing of fuel enriching valve 35 on its corresponding air bleed hole 69 to enrich the fuel mixture supplied by the carburetor. In this way, when greater power is demanded of the engine, the fuel-air ratio is increased.

On the other hand, if while running at normal operating speed, the power demand of the engine is decreased by releasing accelerator pedal 21 and thereby partly closing throttle valve 39, then voltage E1 is increased. This causes a corresponding reduction in the potential difference applied to the input terminals of differential amplifier 11. When its output voltage E3 drops below the breakdown voltage of Zener diode Z1, fuel leaning circuit 25 is operative to cause operation of fuel leaning solenoid 29. It may therefore be seen that upon low power demand, the fuel-air ratio is reduced.

It should be here understood that with conventional carburetors, during so-called "overrun" conditions, i.e., when the accelerator is completely released while the engine is turning at speeds very much higher than idle, the throttle valve is prevented from closing completely even though the accelerator pedal is completely released. The throttle is kept partially open, typically by a vacuum operated diaphragm (not shown), to prevent the resulting high manifold vacuum from drawing excess fuel through the low speed jet 57. Thus, throttle valve 39 does not immediately completely close when accelerator pedal 21 is released while the engine is turning at higher rotational speeds.

It may therefore be appreciated how the present control reduces the amount of fuel supplied to the engine during overrun and thereby improves economy and reduces undesirable exhaust emission. Since releasing accelerator pedal 21 causes voltage E1 to be reduced and thereby reduces the output voltage E3 of the differential amplifier, fuel leaning circuit 25 operates to cause opening of fuel leaning valve 33. Since, during overrun, the engine causes considerable air to be drawn through booster venturi 41 as long as throttle valve 39 remains open, then a partial vacuum is induced in fuel delivery tube 43. Since, during this phase of operation, the engine is coasting or is developing negative torque by dynamically braking the vehicle, then any fuel supply to the engine is essentially wasted by being exhausted without having been fully burned. The leaning of the fuel mixture by opening fuel leaning valve 33 causes a reduction in the amount of wasted fuel delivered to the engine during overrun. Alternatively, fuel supplied to the engine during overrun may be reduced by utilizing an air bleed mechanism such as described herein to supply bleed air to the chamber surrounding idle valve 59 or to passage 63 thereby causing a reduction in the amount of fuel drawn through idle jets 57 and 61, when the accelerator pedal is released while the engine is turning with considerable rotational speed.

Finally, the operation of the control may be considered when the engine is turning with relatively high r.p.m. When this is the case, the voltage E2 supplied by tachometer generator 13 is a considerably high negative potential. If accelerator pedal 21 is partly depressed, then voltage E1 is not very great. Accordingly, a relatively low or substantially zero output voltage E3 is supplied to sensor 23 by differential amplifier 11. As long as this voltage is below the breakdown voltage of Zener diode Z1, then fuel leaning circuit 25 is operative to cause energization of leaning solenoid 29, thereby permitting bleed air to pass through air bleed hole 67, reducing the fuel-air ratio to provide the desirable lean fuel mixture required by the engine under these conditions.

If, however, greater power of the engine is demanded, additionally depressing accelerator pedal 21 moves wiper 19 to cause an increase in voltage E1. This increases the output voltage E3 of the differential amplifier. When this output voltage exceeds the breakdown voltage of Zener diode Z1, fuel leaning circuit 25 ceases to be operative and a normal fuel-air ratio is supplied to the engine. In this way, an increased power demand increases the fuel-air ratio.

But if accelerator 21 is completely released, fuel leaning circuit 25 is caused to become once more operative by the decrease of output voltage E3. Thus, during overrun, the decreased power demanded of the engine is met with a corresponding reduction in the fuel-air ratio.

It is therefore seen that the fuel-air ratio of the fuel mixture supplied by carburetor C to the engine is altered in correspondence with the power demanded of the engine by the operator, this power demand being related to the operating parameters of the engine, that is, its rotational speed and throttle opening. By thereby tailoring the fuel-air mixture to correspond with the power demanded of the engine and thus permitting a leaner fuel mixture during modest power demands, greater fuel economy is attained with a corresponding reduction in the levels of undesirable exhaust emissions. The "weighting" of these operating parameters may conveniently be varied to suit a particular application by varying R2, R3, R4, R6 and R6', as may be appreciated from the equation determining output voltage E3. There is therefore provided convenient predetermination of the fuel-air control signals as functions of the engine operating parameters.

While the present control has been illustrated as controlling the fuel-air mixture supplied by the carburetor by means of solenoid operated air bleeds for the fuel passages of the carburetor, the control may readily be employed to alter the fuel-air ratio in other ways, either for use with float-type carburetors or those employing fluidic control, or with fuel injection controls. Though preferably utilized with reciprocating internal combustion engines, the present control may also find application with other types of engines, e.g., a gas turbine engine. Furthermore, the present control may be used for automotive control functions other than fuel control, e.g., for altering other engine functions or vehicle drive train operation.

For the sake of simplicity, sensor 23 has been shown to comprise a single fuel leaning circuit 25 and a single fuel enriching circuit 27. It should be understood that additional circuits similar to circuits 25 and 27 may be provided for supplying additional control signals in response to additional preselected values of the output voltage of the differential amplifier.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the gist of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative.

We claim:

1. Control apparatus for a throttled internal combustion engine operable at different rotational speeds comprising:

voltage comparing means providing an output voltage which varies as a function of the difference between two input voltages applied thereto;

means responsive to the rotational speed of the engine for generating a first input voltage for said voltage comparing means which varies as a function of said rotational speed;

means for providing a second input voltage for said voltage comparing means which varies as a function of said throttle opening;

a sensor responsive to at least one preselected level of the output voltage of the voltage comparing means for supplying a corresponding control signal which is a predetermined nonlinear function of both the rotational speed and throttle opening of the engine whereby said control signal is supplied according to the power demanded of the engine; and

means responsive to the control signal for effecting a control function.

2. Control apparatus as set forth in claim 1 wherein said sensor comprises a plurality of sensing circuits each having a Zener diode for sensing the output voltage of said comparing means, each circuit supplying a control signal at a predetermined level of the output voltage.

3. A fuel control for varying the fuel-air ratio of a throttled internal combustion engine operable at different rotational speeds in response to the operating parameters thereof, comprising:

voltage comparing means providing an output voltage which varies as a function of the difference between two input voltages applied thereto;

means responsive to the rotational speed of the engine for generating a first input voltage for said voltage comparing means which varies as a function of said rotational speed; means responsive to the throttle opening of the engine for providing a second input voltage for said voltage comparing means which varies as a function of said throttle opening;

a sensor responsive to preselected levels of the output voltage of the voltage comparing means for supplying control signals corresponding to respective preselected levels of said output voltage, said control signals being predetermined nonlinear functions of both the rotational speed and throttle opening of the engine whereby said control signals are supplied according to the power demanded of the engine;

means for controlling a fuel leaning mechanism of the engine in response to a first control signal indicating a decreased power demand of the engine thereby to decrease the fuel-air ratio of the engine; and

means for controlling a fuel enriching mechanism of the engine in response to a second control signal indicating an increased power demand of the engine thereby to in-

crease the fuel-air ratio of the engine.

4. A fuel control as set forth in claim 3 wherein said fuel enriching and fuel leaning mechanisms are solenoid operated air bleeds for the fuel passages of a carburetor for the engine.

5. Control apparatus as set forth in claim 3 wherein said sensor comprises a plurality of sensing circuits, each including a Zener diode for sensing a preselected level of said output voltage.

6. Control apparatus as set forth in claim 5 wherein each of said sensing circuits further comprises a transistor amplifier having a common-emitter configuration, said amplifier operating in response to conduction of said Zener diode.

7. Control apparatus as set forth in claim 6 wherein each of said sensing circuits further comprises a Darlington-coupled pair of transistors and a relay operated by said transistors.

8. Control apparatus as set forth in claim 3 wherein said means responsive to the rotational speed of the engine comprises a tachometer generator.

9. Control apparatus as set forth in claim 3 wherein said means responsive to the throttle opening of the engine comprises a potentiometer having a wiper, the wiper being connected for movement by the engine throttle, whereby the potential at the wiper varies as a function of said throttle opening.

10. Control apparatus as set forth in claim 3 wherein said voltage comparing means comprises a differential operational amplifier.